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ABSTRACT

This study investigates factors which may adversely affect the technical education of Hispanic bilinguals. Hispanic bilingual students (N=36) majoring in science or engineering at the University of Massachusetts were given a variety of exams in both English and Spanish aimed at ascertaining the level of certain mathematically related skills. An English version of the exams was also administered to 38 monolingual science and engineering majors. Results indicate that math performance is very dependent upon language proficiency for bilinguals, but not for monolinguals. (Author/CS)

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SOME FACTORS AFFECTING THE TECHNICAL EDUCATION OF COLLEGE AGE HISPANICS*,†

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ABSTRACT

Factors which may adversely affect the technical education of Hispanic bilinguals have been investigated. The subjects consist of 36 Hispanic bilinguals majoring in a science or engineering at the University of Massachusetts. The students were given a variety of exams in both English and Spanish aimed at ascertaining the level of certain mathematically related skills which are indispensable for a technical major. The English version of the exams was also administered to a norm group of 38 monolingual science and engineering majors. Results indicate that math performance is very dependent upon language proficiency for bilinguals, but not for monolinguals.

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Introduction

It is a well known statistic that surprisingly few Hispanics choose a technical major in college, and that disturbingly few ever complete a full technical program. Through an orgoing research effort at the Bilingual Research Project, we have been trying to identify factors which might adversely affect the cognitive development of technical, bilingual majors and, insofar as possible, separate the factors into those which are language related, and those which are not.

The participants in our study are 36 Hispanic bilinguals majoring in technical subjects at the University of Massachusetts. The breakdown of these students goes as follows: 20 are freshmen, 5 are sophomores, 9 are juniors, and the remaining 2 are seniors; all but 4 are balanced bilinguals - that is, they are equally fluent in Spanish or English. The majority of these students, namely 26, are engineering majors, while the rest are majoring in the sciences (e.g., zoology, chemistry, etc.).

The focus of this paper will be the results of a variety of exams aimed at ascertaining the level of different mathematically-related skills which are essential for any student majoring in a technical subject. These exams, which will be discussed below, were all administered to the bilingual students in parallel form -- that is, there was an English and a Spanish version of each exam. For normalization purposes, the English version of the exams was also given to 38 monolingual students, 29 of which were engineering majors, and the remainder majoring in a science. Of these monolinguals, 33 were freshmen, and 5 were upper class students.

Results

1. Interdependence of Verbal and Algebraic Skills

The first result which I would like to discuss is the apparent difference between monolingual and bilingual students as regards the interdependence

between language and mathematical skills. This study was done by administering to each student a group of three sets of exams. The first set, Test of Reading, Level 5, and Prueba de Lectura, Nivel 5, were developed in 1962 by Guidance Testing Associates[1] to test advanced reading comprehension proficiency. These tests contain three subsections covering vocabulary, speed of comprehension, and level of comprehension. The sum of the number correct in the three subsections will hereafter be referred to as the Total Verbal score. The second pair, Short Algebra Problems - English and Spanish, consists of simple problems in basic algebra requiring little semantic processing. The last pair, Long Word Problems - English and Spanish - are word problems requiring semantic processing and translation from verbal language to mathematical language (equations). The short algebra problems are aimed at assessing a student's algebraic ability which is an essential skill for majors in a technical subject. The Long Word Problems are intended to assess a student's ability to read a mathematics problem in verbal form, translate the problem to mathematical terminology, and solve it.

The means and standard deviations for these three groups of exams are shown in Table I. Also shown is the mean Grade Point Average, based on a maximum of 4.0, for all the students in each sample. Table II contains the correlation coefficient, R, for various pairs of variables. The three numbers in each box of Table II correspond to the value of R obtained when the variable at the left is correlated with the variable at the top of the column for a) monolingual students, b) bilingual students in English and c) bilingual students in Spanish. The correlation coefficient, R, is essentially a measure of how well one variable can be related to another via a linear relationship. The square of the correlation coefficient, R^2, is equal to the fractional variance accounted for by the

Table I. Means and Standard Deviations for Bilinguals and Monolinguals

	Monolinguals N = 38	Bilinguals N = 36 English	Bilinguals N = 36 Spanish	Maximum Possible Score
Grade Point Average	2.72 ± .56	2.37 ± .80		4.0
Short Algebra Problems	32.2 ± 6.3	20.7 ± 8.8	23.1 ± 8.3	40.
Long Word Problems	17.2 ± 4.6	9.3 ± 4.4	11.1 ± 6.1	30.
Total Verbal	89.6 ± 12.4	66.2 ± 19.5	61.9 ± 20.1	125.

Table II. Correlations Among Variables From Table I

	Grade Point Average	Short Algebra Problems	Long Word Problems	Total Verbal
Grade Point Average	1	X	X	X
Short Algebra Problems	.48[c] .46[c] .49[c]	1	X	X
Long Word Problems	.36[a] .74[d] .62[d]	.47[c] .66[d] .59[d]	1	X
Total Verbal	.33[a] .52[d] .55[d]	.02 .43[c] .55[d]	.37[a] .62[d] .53[d]	1

The first, second, and third entries in each box correspond to monolinguals, bilinguals in English, and bilinguals in Spanish, respectively.

Significance Levels: a = .05, b = .01, c = .005, d = .001

linear fit, and is a measure of the "goodness" of the fit. Also shown in Table II are the significance levels, P, for each of the correlations.

The first striking result in Table II is the vanishingly small correlation between monolingual's Total Verbal score and the Short Algebra Problem score (R = 0.02). This result implies that ability to do short algebra problems and verbal ability are relatively independent skills. That is, the fact that a monolingual engineering major can do short algebra problems has absolutely no implication about his/her verbal skills and vice versa. On the other hand, there is a significant correlation (R = 0.43 in English, R = 0.55 in Spanish) between verbal ability and ability to solve short algebraic problems for bilinguals; in other words, if a bilingual technical major picked at random has facility solving short algebra problems, there is a significant probability that he/she will also have high verbal ability.

It can be seen from the entries in the first column, second row of Table II that GPA correlates equally well with Short Algebra Problem score for both groups of students. GPA correlated with Total Verbal score, however, indicates that verbal skills influence the GPA of bilinguals much more strongly than for monolinguals. It is, therefore, not surprising that the correlation between the Long Word Problem score and GPA is so high for bilinguals since the Long Word Problem exam requires not only basic math skills but also substantial verbal skills. This point is corroborated by the strong correlation between the Total Verbal score and Long Word Problem score (R = 0.37 monolingual, R = 0.62 bilingual).

2. Dependence of Algebraic Performance upon Verbal Context

Another pair of exams have yielded very interesting results which shed some light upon how the level of mathematical performance can be influenced by the degree of verbal skills necessary to process the problem. The first exam

consists of Terse Word Problems requiring only very elementary algebra for solution. The other exam consists of equally simple algebraic but very Verbose Word Problems. Both exams are completely equivalent in the mathematical sense. That is, every problem on the latter exam corresponds to one on the former exam but is disguised in technical jargon which may prove intimidating to the student. There are 10 problems in each exam and the questions are graded on a 1-point basis. The means and standard deviations of both the monolingual and bilingual groups are shown in Table III. The column labeled Spanish under the bilingual group corresponds to a Spanish version of the above two exams.

Table III. Means and Standard Deviations for Terse, and Verbose Word Problem Exams

	N = 38 Monolinguals	Bilinguals N = 36 English	Spanish	Maximum Possible Score
Terse Word Problems	9.34 $\pm$ .82	8.22 $\pm$ 1.71	6.97 $\pm$ 1.98	10
Verbose Word Problems	8.84 $\pm$ 1.18	6.94 $\pm$ 2.48	4.31 $\pm$ 2.48	10

As expected, both groups performed worse on the verbose problems. Since these problems require a greater facility with language, the larger difference-mean for bilinguals (D = 8.22 - 6.94 = 1.28 for bilinguals as compared to .5 for monolinguals) is not surprising. A paired T test on the difference score (which is completely equivalent to a repeated measurement analysis of variance) between the Terse and Verbose exams yielded a value of T = 2.56 for monolinguals which is significant beyond the 0.01 level; for the bilingual group in English, a value of T = 5.10 results which is significant beyond the .0005 level. Both of these results clearly indicate the proclivity for students to err as soon as mathematics is combined with verbal material. In fact, not only does a

statistically significant T test result for both monolingual and bilingual groups separately, but a T test on the difference-mean between the two groups yields a value of 2.45 significant at the 0.01 level. This indicates that even in technical areas, where one might believe that language ability is of secondary importance, verbal skills remain an important factor in the performance of a bilingual student.

3. Evidence for Poor Problem-Solving Skills

Finally, I would like to present our findings about the relative level of problem-solving skills between the bilingual and monolingual samples of students. The results of our Formula Translation exam, which requires only rudimentary algebraic and language proficiency, implies that bilingual students are much more prone to make certain simple and eminently avoidable errors than their monolingual counterparts. In this exam, students read a sentence stating a relationship between two variables, and then write an equation expressing the relationship. A typical problem which will be discussed in detail below is: "Write an equation using the variables S and P to represent the following statement: There are six times as many students as professors at this University. Use S for the number of students and P for the number of professors."

Table IV. Means and Standard Deviations on Formula Translation Exam

N = 38	Bilinguals N = 36		Maximum Possible
Monolinguals	English	Spanish	Score
8.9 $\pm$ 4.7	5.5 $\pm$ 4.1	5.2 $\pm$ 4.3	14

Research being conducted by the Cognitive Development Project at the Physics Department of the University of Massachusetts on problems like the one above have shown that the error where the variables are reversed is very common. That is, students are likely to write 6S = P rather than the correct response 6P = S. The means and standard deviations on a 14-question exam (maximum of 14 points score) of problems similar to the one described above is shown in Table IV. The results on the "students and professors" question deserves detailed attention. Combining the results of the 38 monolinguals we have tested with 150 Freshmen engineering students tested by the Cognitive Development Project yields a fairly large N of 188. A chi squared analysis of this problem between the 36 bilinguals and the 188 monolinguals yields a value of $\chi^2 = 11.1$ which for one degree of freedom is significant beyond the .001 level.

Several interpretations of these results for monolingual engineering majors are presented in Clement et al.[2] For bilingual students, we feel that the difficulty is a combination of two factors. The first and most important is that all students have very poor verification capabilities. A simple check made by setting S = 1 in the incorrect equation shows that when there is one student there are six professors, in obvious contradiction to the problem statement. This habit of checking an answer is something we find virtually nonexistant among bilingual students. Another possible explanation of these results is that the phraseology of the problem is particularly confounding to bilinguals. We find no evidence for this interpretation but have not yet investigated the question thoroughly.

Conclusions

It should be noted at the outset that our conclusions must remain tentative at this time as a full and detailed analysis of the data has not yet been completed. We are currently in the process of examining our results by individual student, exam and problem to see if any specific language or conceptual diffi-

culties can be identified. Such a detailed analysis may help us understand why the observed correlations have occurred, but it seems unlikely that any of our general conclusions could change significantly.

Based upon our analysis so far, we believe that the following conclusions are warranted:

1) The overall performance of bilinguals majoring in technical areas, as measured by Grade Point Average, depends at least as much on verbal skills as on mathematical skills. This does not appear to be the case for the equivalent monolingual group.

2) The ability of bilinguals to perform at technical matters at a level at which they are mathematically competent is strongly influenced by the amount of verbal information that they must process.

3) The level of verification capabilities and elementary problem-solving skills are significantly lower for the bilingual group.

I would now like to enter the world of conjecture and discuss a few impressions and ideas that we have. First, the fact that the bilingual students have higher overall verbal proficiency in English implies to us that there would be little, if any, educational advantage gained by offering college-level technical subjects in Spanish, at least as regards students who have proceeded as far academically as those in our sample. Any advantage that might be gained by working in a more familiar, though not necessarily more proficient, language would be offset by the need to learn an entirely new technical vocabulary.

We have a number of ideas which might account for the strong correlation that we observe between the level of mathematical and verbal skills for bilinguals. This might be due to the fact that bilinguals have not yet achieved

some critical threshold in either language.[3] If this were true one would expect the correlation to be primarily due to students with low or intermediate langu ge and math skills, while the correlation between these skills for bilinguals with high proficiency should be weak, as it is for monolingual students. We are currently investigating this hypothesis.

There is another possible explanation for this strong correlation, one which is far more speculative but very interesting and exciting. It has to do with the role played by any second language, and here we would consider mathematics as a second language, in the formation and development of certain mental structures. To the extent that one is willing to define "education" as the adoption of sophisticated logical mental structures, then it may be true that bilinguals, although they may have poorer technical background and fewer facts at their disposal, are actually more "educated" than their monolingual peers. Any second language has the advantage of being free of the personal bias and familiarity of a first language. This familiarity with a first language may cause one to take certain of the logical structures of this language for granted. On the other hand when learning a second language, one is usually more willing to entertain that this new language has a well-defined internal logical structures, and learning these should help one identify similar structures *within* the first language. Knowledge of a second language also permits the development of logical equivalence mappings *between* the two languages. Because the technical bilingual actually has at least three languages, counting mathematics, these *mapping structures* should be much more rich than those of a technical monolingual, explaining the large correlation between language and mathematics performance that we observe for bilinguals.

The above viewpoint is not really original. Needless to say the entire question of development of mental structures and the role played by language is an extremely complex problem of learning theory that will not be solved quickly or easily. Nevertheless, the study of bilinguals may provide a unique area for the creation and testing of learning theory hypotheses. We believe that the prospects for real progress in this area are very good and we are enthusiastic about the future.

We would like to thank the Cognitive Development Project for the use of their results and Dr. J. Lochhead for helpful discussions.

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